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SOME VARIETIES OF INDIAN GRAM

(*Cicer arietinum*, L.)

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I. INTRODUCTION.

In spite of the fact that gram (*Cicer arietinum, L.*) is an important cold-season food-grain in a large portion of the Indian Empire and also in South Europe, little attention has hitherto been paid to this plant. It is not one of the crops mentioned in Fruwirth's *Die Züchtung der landwirtschaftlichen Kulturpflanzen*, an omission which indicates that this plant has not attracted the attention of plant-breeders.

In India, including the Native States, the area under gram every year is roughly 18,000,000 acres, of which about a quarter is contributed by the Province of Agra. Practically all the cultivation is found in the Indo-Gangetic alluvium and on the adjacent portions of the Central Provinces, Central India, and Rajputana. Watt, in the *Commercial Products of India*, states that a line drawn from Bombay to Patna would approximately divide India into two sections, the northern being the great gram area and the southern that in which gram is a subordinate crop. Much of the gram produced is grown in the form of a mixed crop with wheat or barley. The area and yield in the different Provinces are given in the table below. It will be seen that the average yield in British India is 688 lb. per acre.

TABLE I.

Area and average yield of gram in 1911-12.[1]

Province	Area (in acres)	Yield (irrigated) in lb. per acre	Yield (unirrigated) in lb. per acre
Assam	905	...	...
Bengal	176,700	...	881
Bihar and Orissa	992,100	...	881
Oudh	1,697,097	950	800
Agra	5,175,443		
Punjab	4,099,894	625	534
North-West Frontier Province	174,119	730	449
Sindh	76,439	476	...
Bombay	422,274	1,200	420
Central Provinces	993,113	...	532
Berar	117,221	...	...
Madras	134,900	...	...
Upper Burma	38,905	...	414
Lower Burma	1,377	...	...
Ajmer Merwara	26,176	...	...
Coorg	1,540	...	...
Pergana Manpur (Central India)	678	...	...
Total—British India	14,128,881	Average yield 688 lb. per acre.	
Total—Native States	4,039,929		
GRAND TOTAL	18,168,810		

The grain is an important food for man and cattle while the dried stems and leaves are used as fodder. There is a general idea among the cultivators that a gram crop improves the land, a result probably due to the fact that it is a deep-rooted, leguminous crop which also adds a good deal of organic matter to the soil by the fall of the leaves before it is reaped. The pods and leaves produce an acid secretion, a fact which has been known from the remotest antiquity. Watt[2] states that this secretion is composed of malic and oxalic acids and that it is systematically collected by spreading clean cotton cloths

[1] *Agricultural Statistics of India for the years* 1907-08 to 1911-12, Calcutta, vol. I. 1913, pp. 120 and 387.

[2] Watt, *Commercial Products of India*, 1908, p. 300.

over the growing plants at night and collecting from these the vinegar with which they have become charged. This substance is used both medicinally and in diet.

Most of the gram grown is consumed in India but, of late years, the export trade has increased, particularly from Karachi. The export figures for the last six years are thus stated in the *Review of the Trade of India in 1913-14*:—

	Tons
Average of previous three years	148,563
Export in 1911-12	346,742
Export in 1912-13	144,919
Export in 1913-14	70,000

Taking the year 1912-13 as an example, the export of gram to the whole British Empire reached 879,489 cwt. of which 697,767 were sent to Great Britain. The remainder was principally exported to Ceylon (87,068 cwt.), Straits Settlements (36,822 cwt.), and to Mauritius (41,161 cwt.). A much larger quantity (2,018,895 cwt.) found its way to foreign countries, the principal importers being Germany (1,008,075 cwt.), France (698,049 cwt.), and Belgium (138,870 cwt.). All the large ports were concerned in this trade but the bulk (2,087,888 cwt.) was shipped from Karachi. Bombay (672,686 cwt.) and Calcutta (102,987 cwt.) came next in order while the share of Madras and Burma was small.[1]

The experience obtained at Pusa in the cultivation of gram throws a considerable amount of light on the needs of this crop and on its present distribution in India. As regards soil, the best returns have always been obtained on light, high-lying, well-drained land which is not in very good condition as regards fertility. The time of sowing is also important. The best yields have been realized when the crop has been put in rather late, during the first week in November, by which time the light lands have had time to lose a good deal of their moisture. Any deviation from these conditions, as regards soil and time of sowing, has always led to trouble and loss. Grown on heavy, moisture-retaining plots, such as are most suitable for wheat, gram grows rapidly at first and there is every promise of a high yield. After flowering time, however, it is observed that the plants begin to show signs of wilt and very few pods set seed. The crop seems to wither away in spite of the fact that the soil contains abundance of moisture. Early sowing, even on the light lands which suit

1 *Annual Statement of the Sea-borne Trade and Navigation of British India with the British Empire and Foreign Countries*, vol. I, 1913, p. 594.

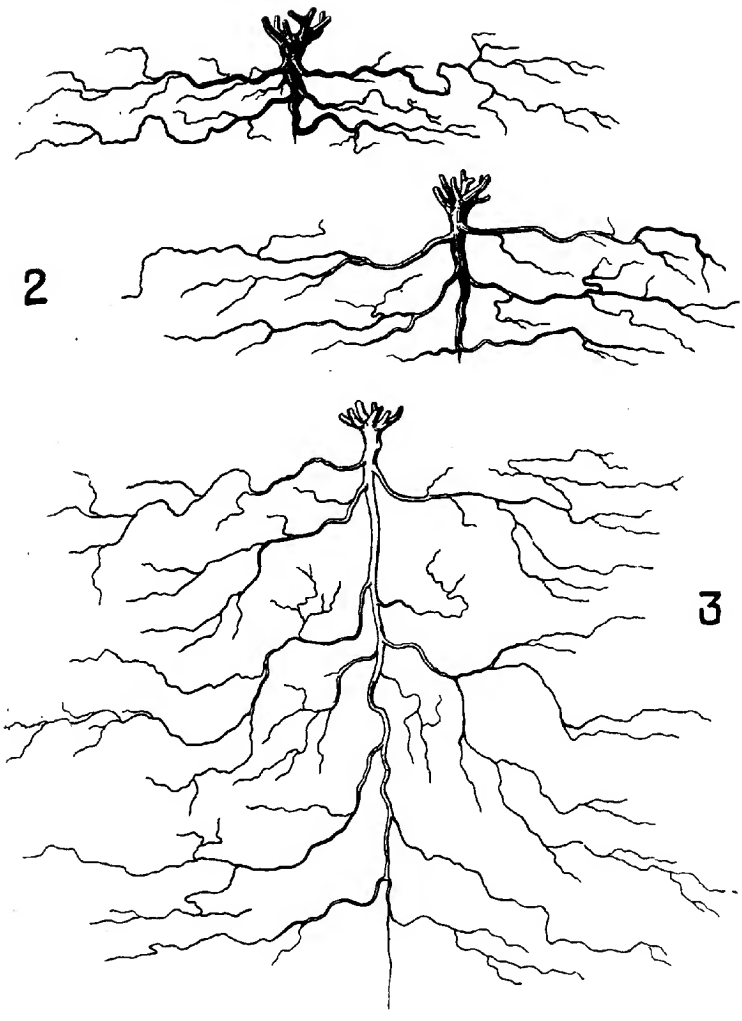
gram, leads to excessive vegetative growth before flowering time and to badly ripened seed. The effect of the type of soil on the yield of the same varieties is well seen in the results obtained on light and heavy land in 1912 and 1913 at Pusa. These are given in the following table :—

TABLE II.

Yield per acre of gram varieties at Pusa in 1912 and 1913.

Variety	1912 (light land)		1913 (heavy land)		
	Mds.	Srs.	Mds.	Srs.	
Local	14	27	4	0	West side of plot in 1913, land very heavy.
Type 14	23	35	3	24	
Type 17	30	31	3	22	
Type 9	32	16	15	8	
Type 16	13	28	10	0	
Type 18	34	27	9	28	East side of plot in 1913, land moderately heavy.

The behaviour, at flowering time, of the varieties grown on heavy wheat land in 1913 was quite unexpected. The whole plot, up to the end of January, gave promise of a record yield. After flowering, however, signs of weakness began to appear—the leaves commenced to fall and little setting took place, particularly towards the west side where the land was heaviest. All the symptoms pointed to root trouble of some kind and accordingly complete plants were dug up and the soil round the roots carefully removed by washing. It was found that the root-system was very superficial and somewhat diseased, particularly in the case of those plants which set no seed. No healthy nodules could be found on the roots of such plants. Where a few seeds only had set, the root development was somewhat deeper and more healthy with a few nodules but the characteristic of the whole set of varieties on the heavy land was superficial rooting and poor nodular development particularly where the soil contained most clay. Healthy plants, on higher, lighter land, were found to have normally developed root-systems and abundant, healthy nodules. The results obtained, as far as root development is concerned, are seen in Plate I opposite. Fig. 1 shows the root-system in the case of a plant which set no seed, while Fig. 2 shows that of a plant of the same kind which carried a few seeds. A normally developed root-system, drawn on the



SOIL-MOISTURE AND ROOT-DEVELOPMENT.

same scale, is shown in Fig. 3 which represents a plant from light, high-lying land about a hundred yards away.

Both as regards yield of grain, depth of rooting, and nodular development, the Pusa results of 1912 and 1913 are most significant. They show unmistakably the cardinal importance of thorough aeration of the soil for the development of an adequate root-system and for the production of healthy nodules. They also serve to explain the present distribution of gram in India and the damage to this crop which so frequently results when the air-supply of the roots and of the nodules is interrupted.

The distribution of gram in India has been referred to in Table I above (p. 214). If the Gangetic alluvium is considered, it will be seen that the area in Bengal is 176,000 acres while in the Province of Agra it is no less than 5,175,433 acres, there being a gradual increase in acreage through Bihar and Oudh. From the Meerut Division of Agra to Bengal, there is a regular soil transition from a somewhat sandy, open, well-drained loam with a relatively small proportion of natural soil moisture to an exceedingly fine silt of high moisture-retaining capacity. As the soil alters in texture towards Bengal, so the area under gram falls. In the Meerut Division, the soils are so open and aeration is so easy that the gram crop can be watered by canal irrigation with advantage but this is harmful at Pusa even on the lightest soils. Thus the distribution of this crop in the valley of the Ganges corresponds closely with the natural aeration of the soil. Wherever the roots of gram can obtain an abundant air-supply, the area is large. As the alluvium becomes finer and closer towards the Bay of Bengal, the area falls off and gram is only found on high, light land. Outside the Gangetic alluvium, the only areas where this crop is really important are the Punjab, Central India, and Bombay. In the Punjab, gram does best on sandy, open soils, and does not generally thrive under canal irrigation on such soils as those of the Chenab Colony. In Central India, the plant obtains abundant air for the roots through the natural cracking of the soil on which it is grown, while in Bombay the conditions are not dissimilar. In some parts of the Bombay Deccan, gram is ordinarily irrigated from wells and very high average yields of over 1,200 lb. per acre are common. Under such circumstances, it is interesting to note that the land which suits gram best is a black soil of medium quality and fair depth resting on *murrum*. This layer of *murrum* provides naturally excellent under-drainage. Thus the distribution of gram in India closely follows what may be called the natural ventilation of the soil and the better the aeration, the greater the density of the crop. Irrigation

is usual only in such cases as the Agra Province and the Bombay Deccan where the soils and subsoils are such that the porosity is not destroyed by flooding the surface.

Speaking generally, gram is a precarious crop. There are many references in the Indian literature to this point and to the damage which results if anything untoward happens at flowering time. Frost, lightning and moisture are generally the reasons given for the partial or entire wilting of gram which often takes place about flowering time. The chief cause of the trouble, however, appears to be interference with the air-supply of the nodules and roots, through crusts formed by rain, on soils which easily run together on the surface or become compacted. The roots and nodules easily turn black and die while the branches wilt from the growing point downwards. Heavy rain during growth has a similar effect on gram to that observed at Pusa when it is grown in heavy land well supplied with soil moisture.

The effect of interfering with the air-supply of this crop is well seen in the result of an experiment, carried out in 1915 at Pusa. A strip of gram was irrigated twice, on January 12 and February 25, and on one half of the watered area, nitrate of soda, at the rate of two cwt. per acre, was applied at each irrigation. Watering was found to check the growth, to turn the foliage a lighter green and to depress the yield by nearly 40 per cent. Irrigation, combined with nitrate of soda, had a much more marked effect. The colour of the foliage rapidly became yellow and many of the plants wilted away. The yield was only one-eighth that of the control plot—a reduction of nearly 88 per cent. This result is probably an aeration effect, due to the destruction of the tilth by the nitrate of soda, after which the air-supply to the roots would be greatly impeded.

The influence of the air-supply in the soil on the yield of gram received further confirmation at Pusa in 1915. This was a wet year and the season was not at all favourable for this crop. If the yield is limited by the aeration of the soil, it would be expected that under such conditions late, deep-rooting varieties would not do well and that the best results would be obtained from early-flowering, shallow-rooted types. It happened this year that three varieties, differing in time of flowering and in root development, were grown on a large scale on uniform land and a comparison was made between the yield and the average length of the main tap-root which developed laterals. The results are given in Table III and it will be seen that the yield in a wet year is inversely proportional to the extent of the root-system. For comparison, the yields of 1912, on similar land, in a very favourable year, are given in the last column.

TABLE III.

The relation between yield and root-development in a wet season.[1]

Variety	Date of flowering	Average length of tap-root bearing laterals	Area, in acres	Yield per acre, 1915		Yield per acre, 1912	
				m.	s.	m.	s.
Type 9	Feb. 18th	16 cm.	1·5	12	22	32	16
Type 17	Feb. 4th	13 cm.	1·0	18	9	30	31
Type 18	Jan. 18th	8 cm.	1·0	23	27	34	27

The cultivators themselves, as far as their practice is concerned, recognize that an open soil is best for gram and that air in the soil is more important than moisture. In many parts of the Punjab, sandy soil is considered most suitable for the crop and the surface, after sowing behind the plough, is often left rough. There is no effort to conserve the surface moisture by means of the beam as is so often the case with crops like wheat.

As in other leguminous crops, the presence in the soil, in sufficient numbers, of the nodule organisms is necessary for the rapid growth of gram. Grown on new land for the first time at Pusa, it is observed that the crop is often thin and poor and that the nodules are almost entirely absent. Moistening the soil with water, containing crushed nodules, leads to the formation of these bodies and it is observed that when the crop is repeated the second year on new areas it improves considerably. In extending the cultivation of this plant to new localities, it would probably pay to import a little gram soil with the seed so as to inoculate the land with the nodule bacteria and to grow the crop at least two years before coming to any decision as to its local value.

II. POLLINATION AND NATURAL CROSS-FERTILIZATION.

FLOWERING.

The flowers are borne singly on the branches on short, jointed peduncles, from half to three-quarters of an inch long, which arise opposite the leaves. The lowest buds open first and the cymose arrangement of the flowers is shown in Plate II.

[1] A result, such as the above, brings out the importance of detail in variety trials in India. But for the determination of the depth of the root-system, the reason for the reversal of the 1912 results in 1915 would not have been evident.

The buds open during the day from about 9 A.M. to 4 P.M. and close again the same afternoon a little before sunset. As a rule, they open again the next morning from 8·30 to 10 A.M. and close again finally in the late afternoon. In 1914, observations were made, towards the end of February, on the flowering of five different varieties and, in all cases, the results were similar, the flowers opening on two consecutive days as indicated above. In 1915, more detailed observations were made of the opening and closing of sixteen flowers of one variety the results of which are given in Table IV.

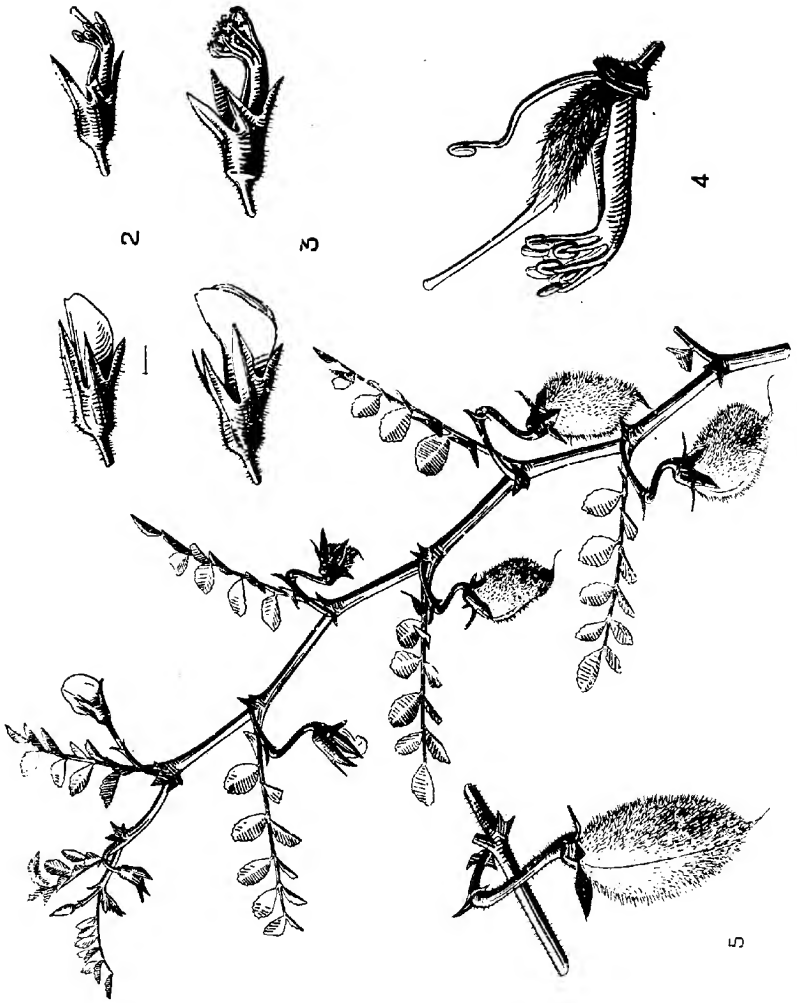
TABLE IV.

Duration of opening of gram flowers.

No. of bud	February 8, 1915		February 9, 1915		Duration of opening	
	Time of opening	Time of closing	Time of second opening	Time of final closing	h.	m.
1	11/44	17/45	8/30	17/20	14	51
2	11/35	17/45	8/30	17/20	15	0
3	11/30	17/20	10/00	18/30	14	50
4	11/15	17/20	10/00	17/20	12	55
5	14/10	17/30	10/00	17/15	11	5
6	14/09	17/30	10/00	17/20	10	50
7	13/30	17/45	10/00	17/45	12	0
8	15/20	16/45			1	25
9	14/20	16/45	Opened partially at 10/30	closed at 16/0	2	25
10	14/00	16/45			2	45
11	15/20	16/45			1	25
12	12/00	16/30	Did not re-open		4	30
13	15/00	17/45	9/20	16/05	9	30
14	15/00	17/45	9/20	17/30	10	55
15					Did not open	
16						

The time during which each flower remains open is therefore somewhat variable and ranges, in the case of those which open normally on two consecutive days, from seven and a half to fifteen hours. As a rule, there is only one flower open at a time on each branch but when the growth is very vigorous two may be open simultaneously. The position of the buds and flowers changes

PLATE



a good deal during the flowering period. In the bud stage, the flowers droop but grow out into the light and air as they open. During the second day, the peduncle begins to be deflexed at the joint and, by the time the flower has faded on the fourth day, the bending is complete. The various stages in the extension and deflexion of the flower stalk are shown in Plate II.

The colour of the corolla soon fades. The pink flowers first turn blue, then colourless and finally brown. The blue flowers retain their colour till they fade. The small pods emerge from the faded corollas about five or six days after the flower finally closes. They attain their full size three or four days later but, at this stage, the seeds are very small and the pods appear empty. From ten to twelve days more are necessary for the seeds to attain their full size in the pod. Flowering goes on in each plant for more than a month but the rapid rise in temperature in March, often accompanied by drying winds, ripens off the whole crop with such rapidity that the last formed seeds have no time to mature in a normal manner.

Pollination.

In the bud stage, the anthers occur grouped round the style at a short distance below the stigma (Fig. 2, Plate II). Dehiscence takes place in the bud a day before the flower opens and, when the pollen is first liberated, the stigma is still above and quite free from the burst anthers. The filaments now gradually increase in length sufficient to carry the burst anthers above the stigma (Fig. 3, Plate II). This stage is completed before the flower opens and thus the act of pollination takes place in the bud. It would be expected therefore that self-pollination is the rule. That this is so is confirmed by the behaviour of ten plants which were placed under nets in 1914. All set normal seed without any difficulty, thereby proving that insect visitors are not necessary to bring about pollination.

Bees visit the flowers in great numbers so that there is some possibility of crossing. On cloudy days, the pollen grains stick together and give out a yellowish, watery substance. In such cases, little or no setting takes place and, even if pods are occasionally formed, no seeds are developed. Such empty pods occur in large numbers in the case of Type 13 and in those plants in the progeny of natural crosses which have rounded seed similar to those of this type. Unproductiveness seems associated with this rounded grain-shape.

Some observations were made in 1915 on the effect of wet, cloudy weather and of moist air on pollination. January 27 and January 28 were both cloudy days and flowers were marked on the morning of the second day just as

they were about to open. The number of pods formed was afterwards determined. The results are given in Table V.

TABLE V.

Effect of cloudy weather on setting.

No. of culture	Total number of marked flowers	Number of pods which formed	Percentage of setting
Type 15	27	11	41
Type 8	9	1	11
Type 7	6	0	0
Type 19	13	0	0
TOTAL	55	12	

The first of these cultures, Type 15, was in full flower at the time of the experiment, the rest were only just beginning to flower.

A more detailed set of observations was made on February 5. February 3, 4 and 5 were wet and cloudy days, during which an inch of rain in all fell. On February 5th, small labels were placed on many branches at a point just underneath the last opened flowers. The flowers just below the labels must have opened during the wet and cloudy weather, while those above opened after the rain. The results are given in Table VI.

TABLE VI.

Effect of rainy weather on setting.

Variety	FLOWERS BELOW THE LABELS			FLOWERS ABOVE THE LABELS		
	No. of flowers	Pods formed	Percentage set	No. of flowers	Pods formed	Percentage set
Type 23	18	2	11	18	15	83
Large Kabuli	18	4	22	18	13	72
Type 22	21	5	23	21	17	81
Type 21	19	1	5	19	12	63
Type 20	20	9	45	20	18	90
TOTAL	96	21		96	75	

The effect of the rainy and cloudy weather was therefore most marked and the setting was only about a fourth of what took place immediately the

weather cleared. The best setting occurred in the case of the last culture which, at the time of the experiment, was in full flower. Unfavourable conditions seem to affect the setting of plants, just beginning to flower or just going off their bloom, much more than those in full flower.

The effect on setting, during bright weather, of moist air round the flower is very similar to that which occurs during rain and cloud. Flowering branches were placed in tubes, closed to varying extents and also in ordinary, elliptical lamp-chimneys, open above and closed lightly with cotton wool below. When the tubes were completely closed and no air circulation was possible, the buds did not open and no setting took place. Where the tubes and lamp chimneys were opened, to varying extents, to the atmosphere and where some air circulation was possible, a little setting took place. In the case of forty buds which opened in large lamp chimneys, open above and lightly closed below with cotton wool, only 8 (20 per cent.) of the flowers set seed.

The experiments indicate the enormous effect of high humidity on setting and show the loss which must follow from even light rain or damp cloudy weather at flowering time. Thus rain at this period may damage the gram crop in two ways—by preventing setting, and if the fall is large, by interfering with the aeration of the roots and nodules causing the whole plant to wilt.

No cases of parthenogenesis occurred at Pusa when the stigma or stamens were removed prior to flowering.

Natural Cross-fertilization.

While self-pollination is the general rule in gram, nevertheless natural crossing occurs occasionally in this crop. The first cases were suspected in 1911 at Pusa when, in a large plot of a pure culture of Type 13, a blue flowered variety, some seeds were observed different in shape and colour from the general plot. These resembled, to some extent, those of Type 9, a white flowered variety, which was growing side by side. These stray seeds were grown singly and in 1912 produced plants with different flower colours—white, blue and various shades of pink. Some single plants, raised from these seeds, were selected in 1912 and their subsequent progeny, as regards flower colour, is given in the following :—

(1) Six plants, with white flowers, bred true in 1913.

(2) One blue flowered plant bred true and three other plants with blue flowers split into blue and white—18 blue : 12 white ; 23 blue : 8 white ; 13 blue : 7 white. This gave a total of 54 blues to 27 whites or a ratio of 2 : 1.

(3) Of eleven plants with various shades of pink flowers, only four bred true as regards flower colour. The rest split as follows :—

No.	Progeny in 1912-13		
	White	Blue	Pink
4	6	4	9
6	7	3	12
8	5	3	10
9	4	3	10
10	9	2	12
12	6	4	10
11	0	4	12

A second case of natural crossing was observed in 1911 in a plot of Type 1, a white flowered variety. Two plants, with pink flowers, were observed in 1912 which split during the next year into—3 white : 11 pink ; 6 white : 12 pink—thus giving a total of 9 whites : 23 pinks.

The single plants of 1913, connected with the above cases of natural crossing, were grown on the following season and the results confirm those of 1913.

Pink flowered plants (17).

(1) Four, which produced 98 plants in all, bred true as regards pink flowers.

(2) Four split into pinks and whites only—7 pink : 2 white ; 12 pink : 5 white ; 11 pink : 2 white ; 51 pink : 18 white—total 81 pinks : 27 whites or a ratio of 3 : 1.

(3) Three split into pinks and blues only—15 pink : 6 blue ; 23 pink : 11 blue ; 27 pink : 10 blue—total 65 pinks : 27 blues or a ratio of 2·4 : 1.

(4) Six split into pinks, blues and whites as follows :—

No. of culture	Progeny in 1914		
	Pink	Blue	White
4 (9)	24	3	8
8 (1)	3	6	2
8 (2)	45	13	8
9 (1)	6	1	2
9 (2)	52	22	27
10 (4)	5	2	2
	135	47	49

White flowered plants (30).

Twenty-eight of these bred true as regards flower colour and splitting took place in two cases only. One culture produced 22 whites and 2 pinks and another gave 8 blues and 9 whites. The former of these was probably a case of fresh crossing, while in the latter there must have been a mistake in observation in 1913.

Blue flowered plants (8).

(1) Three bred true and produced 35 blue plants in all.

(2) Four plants split into blues and whites only—8 blue : 1 white ; 9 blue : 5 white ; 12 blue : 6 white ; 7 blue : 1 white—total 36 blues : 16 whites.

(3) One plant split into 6 blues and 3 pinks.

In addition to the splitting as regards flower colour, there appeared to be segregation, as regards grain shape, into ordinary and rounded grains.

The above observations on the behaviour of the progeny of the natural crosses were not made in sufficient detail for the deduction of the various colour factors present in the flowers. A subsequent critical examination of the types showed that there are several grades of pink flowers.

III. CLASSIFICATION AND DESCRIPTION OF THE TYPES.

The raw material used in the study of this crop consisted of collections of country seed obtained from Aligarh, Muzaffarnagar and Saharanpur in the United Provinces and of collections of local Bihar gram. Form separation was commenced in 1909 and was continued in succeeding years. In all cases, the cultures were started, either from a single seed or from the seed of a single plant.

That the Indian *gram* crop is not uniform but consists of several distinct forms, distinguished by the colour of the seed and of the flowers, has long been vaguely recognized and there are frequent references to these kinds in the literature. The most definite recognition of the existence of these types in the older literature is to be found in the following description of gram in Duthie's *Flora of the Upper Gangetic Plain* (p. 256) :—

"A viscid, much-branched annual. *Leaves* 1-2 in. long, with usually a terminal leaflet ; *stipules* small obliquely ovate, toothed ; *leaflets* about 1·4 in.

long, ovate, oblong or obovate, deeply cut. *Peduncle* 1/4 to 3/4 in., jointed about the middle, deflexed after flowering. *Calyx* 1/4 to 1/3 in., teeth linear. *Corolla* scarcely half as long again as the calyx, pink, blue or white. *Pod* 3/4 to 1 in., turgid, pubescent, topped by the persistent base of the style. *Seeds* obovate or subglobose, beaked, reddish brown, black or white.

Largely cultivated in North-West and Central India during the cold season. Although not now to be found in a truly wild state, its original home was most probably in some part of South-East Europe. Two distinct kinds are grown in this part of India, one with reddish seeds, and a smaller kind with seeds of a light brown colour. There is also one with nearly black seeds and another with large white seeds, known as "Cabuli," the last named is, however, rarely grown for profit."

The characters in which the various varieties and types of gram differ from each other must first be considered before their classification is dealt with.

Morphological Characters.

Beyond the great range in the colour of the flowers and seeds, which occurs in this crop, the differences between the various types are not, at first sight, easy of exact expression. By growing the kinds in oblong blocks, so arranged that they can be compared in the early morning light, the somewhat elusive vegetative differences become much more obvious. The massed habit then becomes useful in distinguishing forms which otherwise would defy classification.

Habit. The group of types—1 to 5 which make up what is known as the "large Kabuli gram" stand out quite clearly from the crop as cultivated under field conditions in India. These have light foliage, white or whitish green flowers and they are considerably taller with larger leaflets than the country crop. Their seeds are much larger than those of ordinary gram and are always whitish in colour.

With the exception of Type 9, the rest of the twenty-five kinds are somewhat similar in general habit apart from the colour of the foliage and time of maturity. The main branches give off, as a rule, not more than one secondary shoot and the general habit is erect. Type 9, however, is quite different in this respect. The crown divides up into several main arms at the surface of the ground and the main branches give off numerous laterals. The extreme range in habit in this crop is shown in Fig. 1. The left-hand sketch shows the

mode of branching most usually observed while, on the right, the habit of Type 9 is represented.

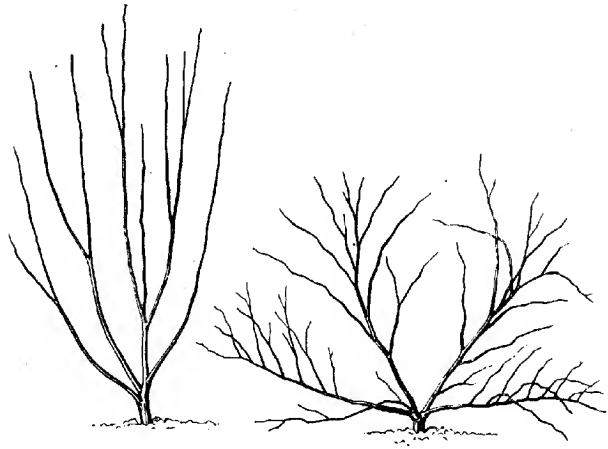


Fig. 1. The range in general habit in gram.

Closely correlated with the habit and time of flowering is the general extent of the root system and the depth to which laterals are developed on the main tap-root. As a rule, the late sorts are more deep rooting than the early types as will be seen on reference to Table III above (p. 219). It has not been usual hitherto, in considering the habits of varieties, to pay much attention to the root-system. A little consideration, however, will make it clear that this will have to be taken up in the future, particularly in the case of Indian economic plants.[1]

Leaves. The types differ considerably both in the total length of the leaf, in the size and number of the leaflets as well as in the tone of colour of the foliage. Types 1 to 5 have comparatively large leaflets and stand out in this respect from the remaining forms. The small colour differences between

[1] The extent of development of the root-system will often assist the investigator in judging of the suitability of a variety for a given tract of country and for a particular set of soil conditions. It is quite possible that the plant-breeders of the future will study the inheritance of characters relating to the root just as minutely as they have done to certain of the above-ground characters dealing with flowers and seeds. In India, where the supply of water and air to the roots is so important, much of the future work on crops is likely to be devoted to the subterranean portions of the plant.

Types 6 to 25 are best studied when the kinds are massed in oblong plots. In a few cases, the margin of the leaflets is red. The large glandular hairs on the margin of the leaflets often contain coloured cell-sap, which may either be yellow, red or blue.

Flowers. The colour of the corolla may be greenish, white or various shades of pink or blue. In fading, the pink flowers turn blue before withering.

Seeds. The colour of the seeds varies from whitish to blackish through various shades of yellow and red. There is a considerable difference in colour in the seeds of any one plant, but this is due to the fact that the last formed grains have no time to ripen on account of the rapid onset of the hot, dry weather.

Classification of the Types.

The twenty-five types of gram, so far isolated at Pusa, can be distinguished according to the following classification provided full use is made of the massed habit and of all the vegetative differences.

I. Plants, leaves, flowers and seeds large.

1. Flowers greenish, standard and wings hairy, standard persistent.

Type 1. Very late, erect, leaves dark green, seeds white with a reddish yellow tinge.

2. Flowers white, corolla glabrous, standard caducous.

A Plants early.

Type 2. Very early, leaflets large.

Type 3. Early but later than Type 2, leaflets rather small.

B. Plants late.

Type 4. Similar to Types 2 and 3 except in time of maturity.

C. Plants very late.

Type 5. Leaves very dark green.

II. Plants, leaves, flowers and seeds small.

1. Flowers white.

A. Seeds white with a yellowish tinge.

(*a*). Plants early.

Type 6. Leaves light yellowish green.

(*b*). Plants intermediate in maturity.

Type 7. Plants spreading, leaves dark green.

Type 8. Later in maturity than Type 7, leaves light green.

(*c*). Plants late.

Type 9. Plants very spreading, main branches bear numerous laterals, foliage very dark green.

B. Seeds yellowish red.

Type 10. Early, erect, leaves dark green.

C. Seeds bluish brown, rounded.

Type 11. Very early, habit very erect, leaves light green.

D. Seeds yellowish brown.

Type 12. Very early, habit erect, leaves light green.

2. Flowers blue.

Type 13. Early, habit erect, seeds small, rounded, bluish brown.

3. Flowers pink.

A. Standard light pink, wings violet above, pink below with a slight bluish tinge.

(*a*). Leaves very dark green.

Type 14. Late, slightly spreading, slight redness on the margins of the leaflets, on the midrib and at the insertion of the lateral branches, seeds dark brown.

(*b*). Leaves dark green.

Type 15. Early, erect, seeds yellowish brown.

(*c*). Leaves somewhat light green.

Type 16. Slightly spreading, seeds dark brown.

Type 17. Rather late, seeds yellowish brown.

(*d*). Leaves light green.

Type 18. Leaves light green with a yellowish tinge, seeds dark brown.

Type 19. Late, seeds yellowish brown.

B. Standard and wings pale pink with a general bluish tinge.

Type 20. Early, very erect, leaves very dark green, seeds yellowish brown.

C. Standard light pink, wings with a general bluish tinge.

Type 21. Late, leaves dark green with a yellowish tinge seeds dark brown.

D. Standard very light pink, wings pink with a slight bluish tinge.

Type 22. Early, leaves light bluish green, seeds dark brown.

Type 23. Rather late, leaves dark green.

E. Standard and wings pink with a deep bluish tinge.

Type 24. Late, seeds very dark brown.

F. Standard and wings reddish.

Type 25. Leaves dark green, seeds reddish brown.

NOTES ON THE VARIOUS TYPES.

Type 1. Very late, habit erect. *Leaves* large, dark green. *Flowers* large, greenish white; *standard* persistent, pubescent, green with a greenish white eye; *wings* slightly pubescent, white with a greenish tinge at the edges; *keel* glabrous, white. *Seeds* large, white with a reddish yellow tinge.

This type stands out from the rest on account of its greenish pubescent flowers and the persistent standard (Fig. 2).

Fig. 2. Persistent standard of type 1

Type 2. Early, habit erect. *Leaves* dark green. *Flowers* large, white; *corolla* glabrous, white. *Seeds* large, white with a reddish yellow tinge.

This early variety appears to be the most prolific of the large white seeded types.

Type 3. This type only differs from Type 2 in its slightly smaller leaflets and in the time of maturity, which is a little later.

Type 4. This type differs from Type 2 only in time of maturity which is distinctly later.

Type 5. This type differs from Type 2 in two respects only—in its very dark green leaves and in the time of maturity which is much later.

Type 6. Early, habit somewhat spreading. *Leaves* very light yellowish green. *Flowers* white. *Seeds* white with a yellowish tinge.

Type 7. Early, habit spreading. *Leaves* dark green. *Flowers* white. *Seeds* white with a yellowish tinge.

Type 8. This type resembles Type 7 in all respects except that the leaves are lighter in colour and the time of maturity is somewhat later.

Type 9. Very late, habit very spreading with numerous side branches (Fig. 1). *Leaves* very dark green. *Flowers* white. *Seeds* white with a yellowish tinge.

This type is of interest in that, in spite of its deep root system, which is a disadvantage at Pusa, it has so far given the highest monetary return per acre. In this form, yield and quality are united in the same type.

Type 10. Early, habit erect. *Leaves* dark green. *Flowers* white. *Seeds* rounded, yellowish red.

Type 11. Very early as regards flowering but late in maturing, habit very erect. *Leaves* dark green. *Flowers* white. *Seeds* much rounded, bluish brown.

Type 12. Very early as regards flowering but late in maturing, habit erect. *Leaves* light green. *Flowers* white. *Seeds* reddish brown.

Type 13. Very early, habit erect. *Leaves* very dark green. *Peduncle* dark blue. *Flowers* blue fading to dark blue; *standard* light blue with a somewhat yellowish light blue eye and violet veins; *wings* deep blue; *keel* blue. *Seeds* small, much rounded, bluish brown.

Type 14. Late, habit slightly spreading. *Leaves* very dark green with slight redness on the teeth of the leaflets and on the midrib. *Flowers* pink; *standard* light pink; *wings* violet. *Seeds* dark brown.

Type 15. Early, habit erect. *Leaves* dark green. *Flowers* pink; *standard* light pink; *wings* violet. *Seeds* brown.

Type 16. Intermediate in time of maturity, habit slightly spreading. *Leaves* somewhat light green with slight redness on the teeth of the leaflets

and on the midrib. *Flowers* pink; *standard* light pink; *wings* violet. *Seed* dark brown.

Type 17. Late, habit slightly spreading. *Leaves* with a yellowish tinge and slight redness on the apices of the teeth of the leaflets, midrib reddish. *Flowers* pink; *standard* light pink; *wings* violet. *Seeds* yellowish brown.

Type 18. Intermediate in time of maturity, habit erect. *Leaves* light green with a yellowish tinge, slight reddening on the margins of the leaflets and deeper reddening on the midrib. *Flowers* pink; *standard* light pink; *wings* violet. *Seeds* dark brown.

This type has given the highest average yield per acre during the last four years at Pusa, namely, 20 maunds 33 seers per acre. This result is probably partly due to the fact that the root system of this form is adapted to the soil conditions in Bihar.

Type 19. This type differs from Type 18 in two respects only—in maturing later and in the lighter brown of the seeds.

Type 20. Matures the earliest of the pink-flowered types, habit very erect. *Leaves* very dark green with slight reddening of the margins of the teeth of the leaflets. *Flowers* pink, but with more blue and less red than in Types 14 to 19. *Seeds* yellowish brown.

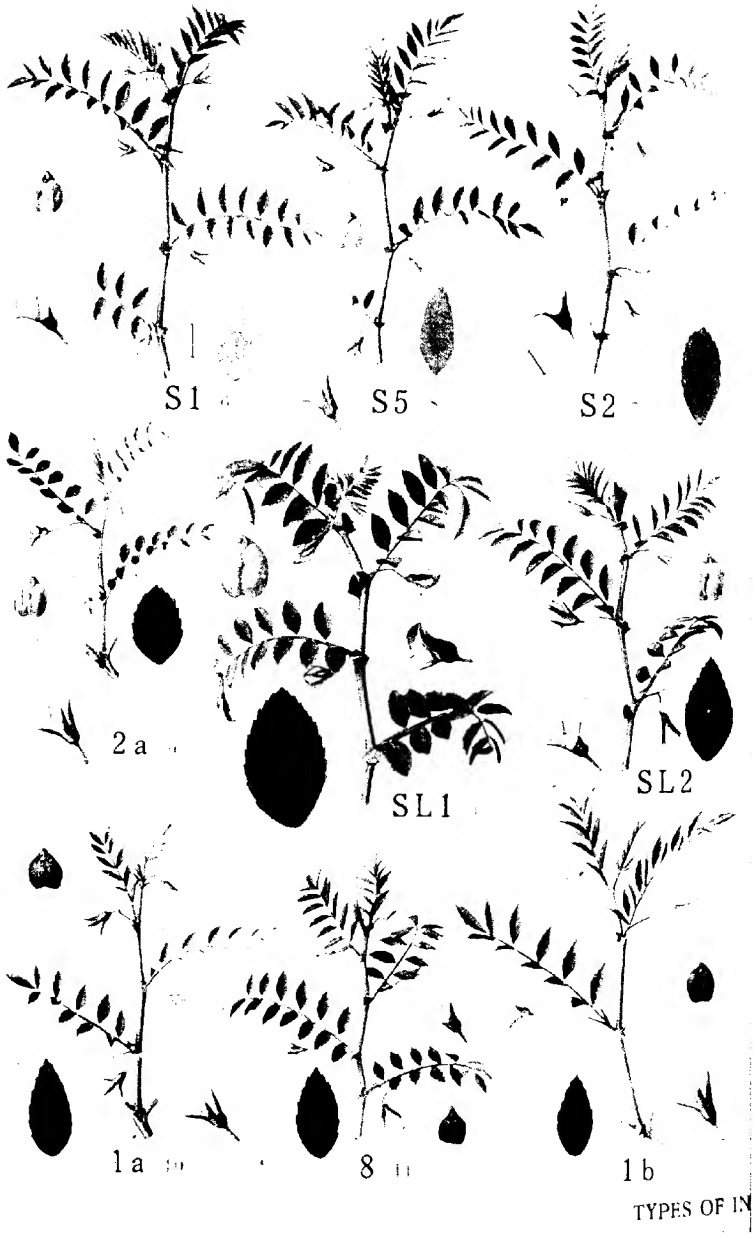
Type 21. Late, habit somewhat erect. *Leaves* dark green with a yellowish tinge. Some redness on the teeth of the leaflets which is strongly developed on the midrib and in the angle at the base of the side branches. *Flowers* pink; *standard* light pink; *wings* pink with a bluish tinge. *Seeds* dark brown.

The red colour on the midrib, in the axils of the leaves and in the angle at the insertion of the side branches is more strongly developed in this than in the other types.

Type 22. Early, habit erect. *Leaves* light bluish green. *Flowers* pink; *standard* light pink; *wings* slightly bluish. *Seeds* dark brown.

Type 23. Closely resembles Type 22 except in slight colour differences in the flowers and in later maturity.

Type 24. Late, habit erect. *Leaves* somewhat light green. *Flowers* pink but with a deeper blue tint than any of the pink-flowered group. *Seeds* very dark brown.



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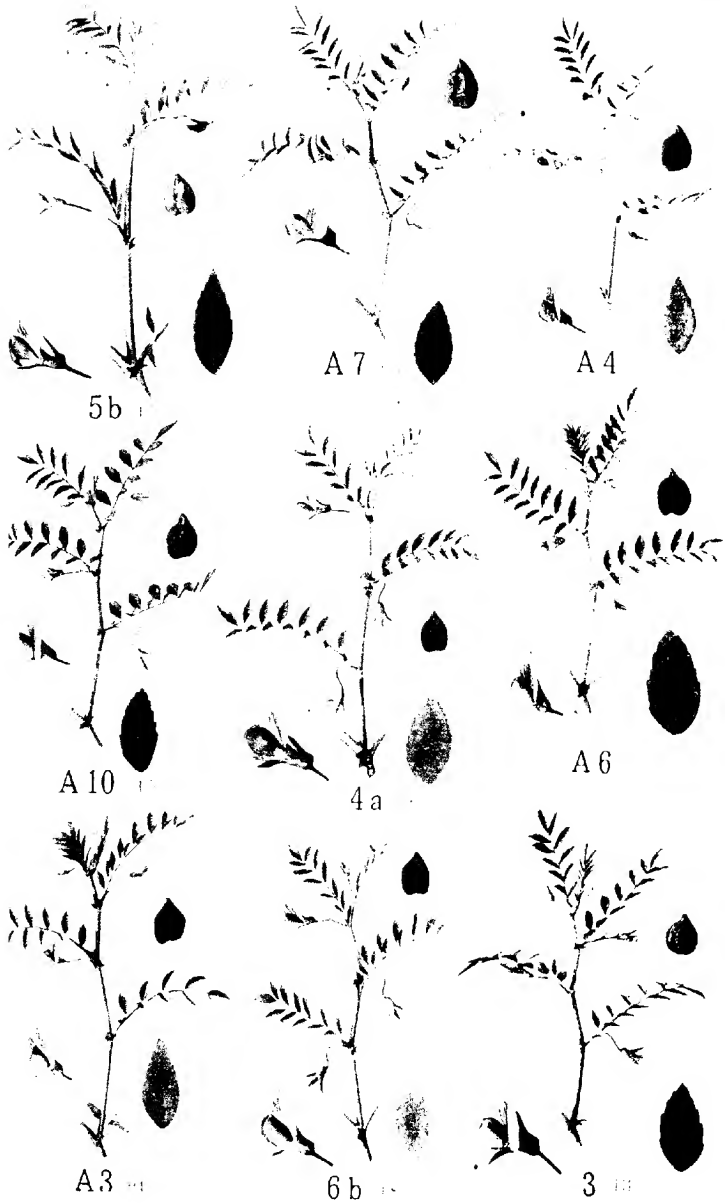
A 7
A 4
5b
A 10
4a
A 6
A 3
6b
3

Type 25. Intermediate in maturity, habit erect. *Leaves* dark green. *Flowers* pink but with rather a deep red shade. *Seeds* reddish brown.

IV. SOME ECONOMIC ASPECTS.

As in many other cultivated plants, the value of a crop of gram depends principally on the yield per acre and to a less extent on the quality of the grain.

YIELD.

The yielding power of a variety of gram depends on several factors such as its power to set seed, habit of growth, extent of root system and time of flowering.

The types of gram grown at Pusa differ to a considerable extent in their power of setting seed. While this matter has not yet been investigated in detail, nevertheless, generally speaking, the kinds with rounded seed such as Type 13 do not set seed easily and, in consequence, the pods are either quite empty or else contain one seed only. The large seeded varieties, Types 1 to 5, are also unproductive and usually have only one seed in each pod.

The habit of the plant, which is really the outward expression of the method of branching, is a factor which, to a great extent, influences yielding power. Within limits, any tendency to branch well tends to increase the yield as the flowers are borne towards the ends of the branches. The greater the number of flowers, the greater the number of seeds. If, however, the formation of the secondary branches unduly prolongs the vegetative period and flowering occurs too late, there may not be sufficient time for normal ripening and the yield will be reduced. In tracts like those of Northern India, where the gram crop often has to be sown early before the surface moisture falls too low for germination and where the growth period is a long one, it is quite probable that a tendency to form side branches will be a distinct advantage.

Closely bound up with the habit of the plant is the development of the root system. The late, much branched, spreading types develop not only a deep tap-root but also produce laterals to a considerable depth. The early, erect forms, on the other hand, have shallower roots both as regards the total length of the tap-root and the extent of the secondary system. As the well-being of gram depends to a large extent on the natural aeration of the soil and on a continuous supply of both oxygen and nitrogen for the roots and nodules, it follows that any tendency to root deeply is only of advantage on deep, open, well-drained land. On thinner soils or on soils where the subsoil is not

sufficiently aerated, the shallow rooting, erect and early flowering varieties are likely to give the best results. This point is well illustrated by the behaviour at Pusa in 1915 of the three kinds referred to in Table III above (p. 219).

The time of flowering is of importance in several ways. Other things being equal, excessive earliness is associated with low yielding power. On the other hand, very late flowering is a disadvantage as the whole of the grain grown in India has to ripen under a rapidly ascending temperature. As the humidity of the air has a great effect on setting and pollination takes place best on bright warm days, the best time of flowering appears to be the end of the cold weather when the season begins to change. There is then ample time for pollination to take place in favourable weather and for the seeds to develop in a normal manner before the hot winds begin. In selecting types for particular localities, the flowering period will probably prove to be important.

At Pusa, a further factor affects the yield, namely, the time of sowing. As mentioned above (p. 215), gram does best when sown rather late, during the first week in November, by which time the surface soil has lost a good deal of its moisture. Late sowing is found to check the tendency to excessive vegetative growth, to keep the plants small and to increase the proportion of seed to stems.

Quality.

Quality in the case of gram is of considerable importance. As in other crops, it is of course essential that the seeds should be large and well-filled. Given well-grown seed, the quality appears to depend on the colour. The lighter the tint, the higher is the price. In 1912, samples of eight varieties of gram grown at Pusa were sent to Messrs. Ralli Brothers, Bombay, for valuation. The results are given in Table VII.

Table VII.

Valuation of gram varieties in 1912.

Type	Colour of grain	Price per cwt., f. o. r. Bombay					
		Rs.	A.	P.	Rs.	A.	P.
9	Whitish	5	8	0			
10	Yellow	4	12	0			
17	Light brown	4	8	0			
Local	Do. do.	4	2	0	to 4	4	0
18	Dark brown	4	2	0			
14	Do. do.	3	12	0			
16	Do. do.	3	10	0	to 3	12	0

The price of the ordinary exportable varieties at Bombay on May 3 1912, when the above valuations were made, was Rs. 4-2-0 to 4-7-0 per cwt., f. o. r., Bombay.

It will be observed that the valuations follow the colour and that the lighter the colour the higher the price. The last three on the list have almost black seeds and have been valued very low. The white gram, on the other hand, fetched the highest price, nearly fifty per cent. more than the lowest. The high price of white gram depends no doubt on the supply but it is clear that colour in gram counts a good deal in the price. The reason of these differences in price appears to be due to the fact that the dark coloured grams exported to Europe are largely fed to animals while the flours of the lighter kinds are used in various manufacturing processes.

One interesting fact comes out of these valuations which should be recorded. The white gram, Type 9, which realized the highest price is an interesting example of the union of yield and quality in the same variety. Grown at Pusa for the last four years on a large scale, on widely varying soils and in very different seasons, this kind has given an average yield of just over twenty maunds per acre. This is the second highest outturn, the best being that of twenty maunds thirty-three seers yielded by Type 18. Taking both yield and quality into consideration and on the basis of the valuation of Messrs. Ralli Brothers, Type 9 gave the best return, an average of Rs. 78-11-0 per acre while the average produce of Type 18, the highest yielder, was worth only Rs. 61-4-0 per acre. The result is another illustration of the value of selection methods in improving Indian crops in the present condition of agriculture in this country. Had an attempt been made by hybridization to achieve such a union of yielding power and grain quality, the work entailed would have been arduous and long continued.

QUETTA,
May 29, 1915.

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